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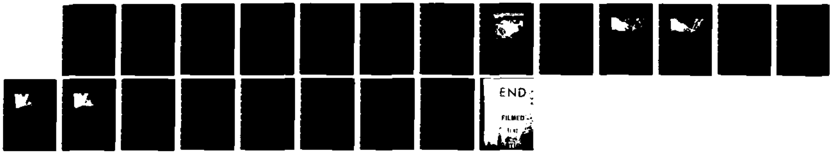

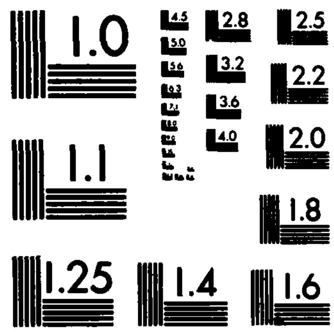
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AD-A133 782

Sound Propagation Through a Coastal Upwelling: Comparison of Modeling Prediction With Experimental Data

A Paper Presented at the 103rd Meeting of the Acoustical Society of America, 26-30 April 1982

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Preface

This document was prepared under joint sponsorship by NUSC and the Naval Postgraduate School (NPS) in accordance with provisions of the NUSC-NPS memorandum of Understanding dated May 1974. NUSC funding was provided through the Independent Research-Independent Exploratory Development (IR/IED) Program Element 61152N, NUSC Job Order A64890, Principal Investigator LCDR J. T. Malay, Code 335M.

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Reviewed and Approved: 22 August 1983

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In a previous paper, modeling predictions were made for the effect of a coastal upwelling on sound propagation. To verify these results, a sound propagation experiment was conducted across a moderately developed upwelling located at the Sur Canyon off the coast of California. A 1-kHz projector was towed through a sonobuoy field which spanned the upwelling region. A supporting oceanographic survey was made to obtain environmental data input for multiprofile modeling predictions. The relative importance of oceanographic and topographic changes on sound propagation were determined. A follow-on (over)

20. (Cont'd)

experiment in a fully developed upwelling is planned.

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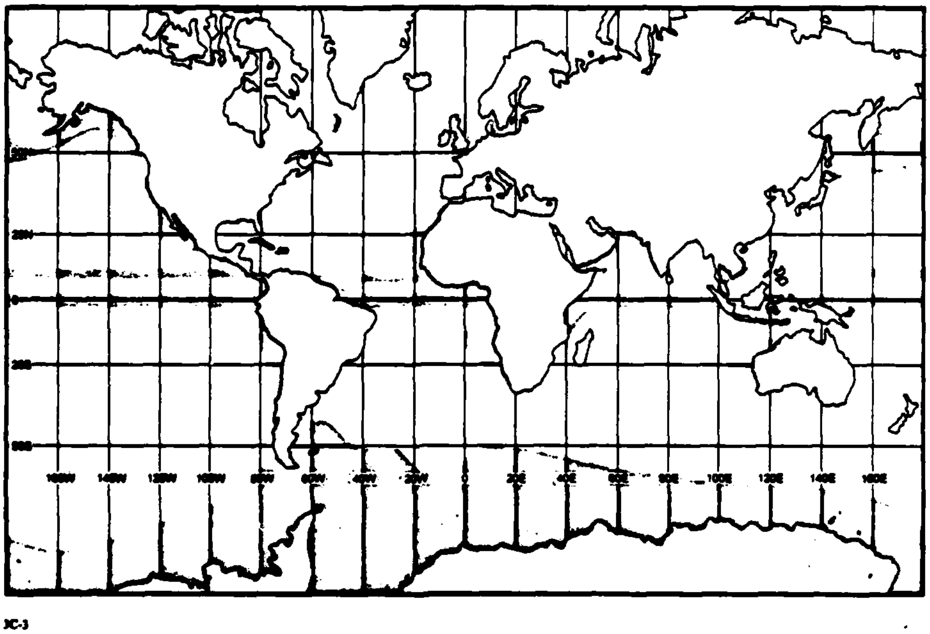
SOUND PROPAGATION THROUGH A MODERATE COASTAL UPWELLING: COMPARISON OF MODELING PREDICTION WITH EXPERIMENTAL DATA

General Areas of World Upwelling



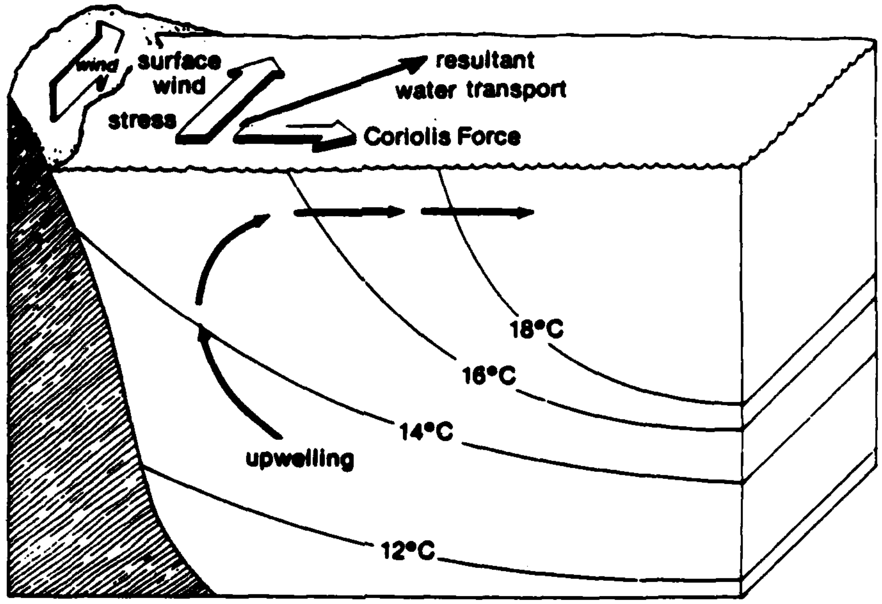
Slide 1

It is well known that prevailing winds determine the circulation pattern in the oceans. However, the wind is also responsible for another ocean phenomenon, called upwelling. As the name implies, deep water, which is generally colder, is upwelled to the surface.

Known areas of upwelling in the world's oceans are shown in slide 1. The upwelled cold water is rich in nutrients, hence these locations tend to be prime fishing grounds. As you can see, many upwelling regions occur along continental margins and are specifically called coastal upwellings. Of particular interest is the upwelling along the California coast.

An upwelling of cold water is going to change the temperature of the water column. That will change the sound-speed profile, which will result in a change in the underwater sound-propagation conditions, which is why we are interested in upwellings.

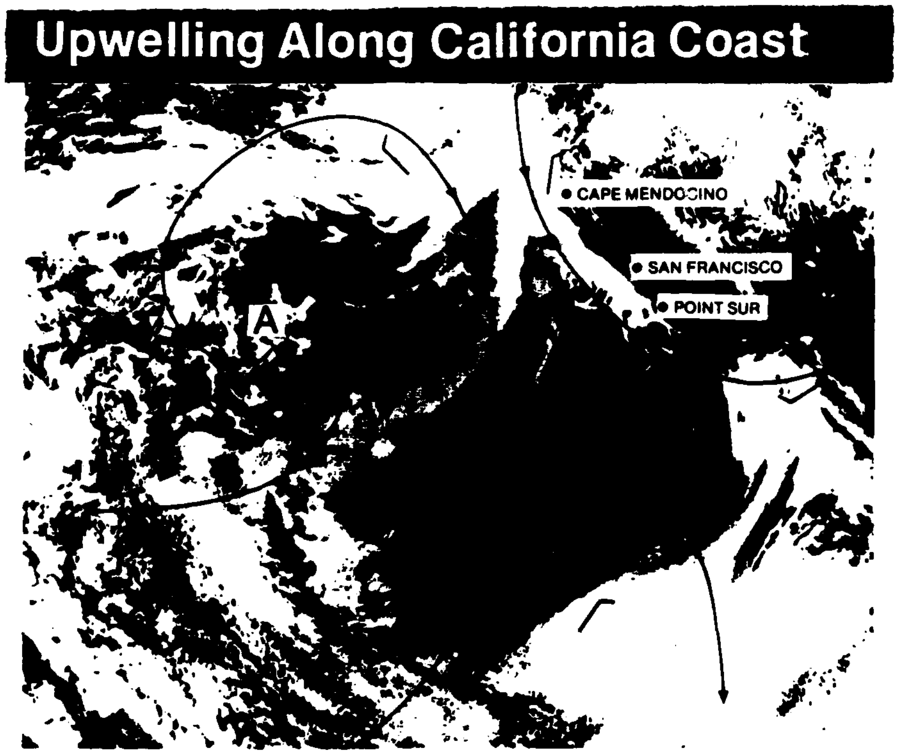
Coastal Upwelling



Slide 2

A coastal upwelling is formed when the surface wind is blowing parallel to the coast in such a way that the Coriolis force is acting away from the shore. For the west coast of North America, this would be a northerly wind. As you see it in slide 2, the wind is blowing down the coast. This results in a transport of surface water away from the coast, and the deeper colder water must upwell to fill this void.

Unlike the case of major ocean currents, this process does not have great momentum so it can vary relatively quickly with time as the wind changes. Generally, these coastal upwellings are occurring where there is a significant slope to the bottom which, of course, can be an important factor in sound propagation.

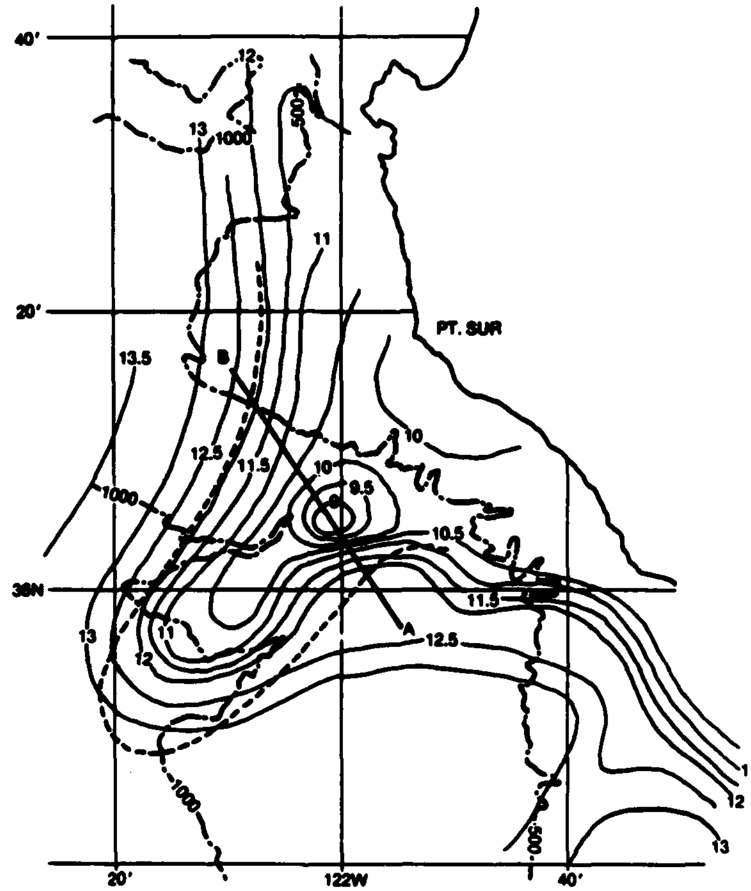


Slide 3

Slide 3 is a satellite image of a classic upwelling development along the California coast. The colder water is shown by the lighter shades. Weather information is overlaid. Streamlines indicate the wind flow, which you can see is northerly down the coast. This is caused by the clockwise circulation about the high offshore.

There is a general upwelling along the coast from Cape Mendocino to Point Sur. Note that there are apparently several favored locations indicated by the out-streaming of a filament-like upwelling plume. Such a plume occurs at Point Sur and it is this particular location that is of interest to us.

Coastal Upwelling Plume Observed Off Pt Sur, Calif. on 1 May, 1979



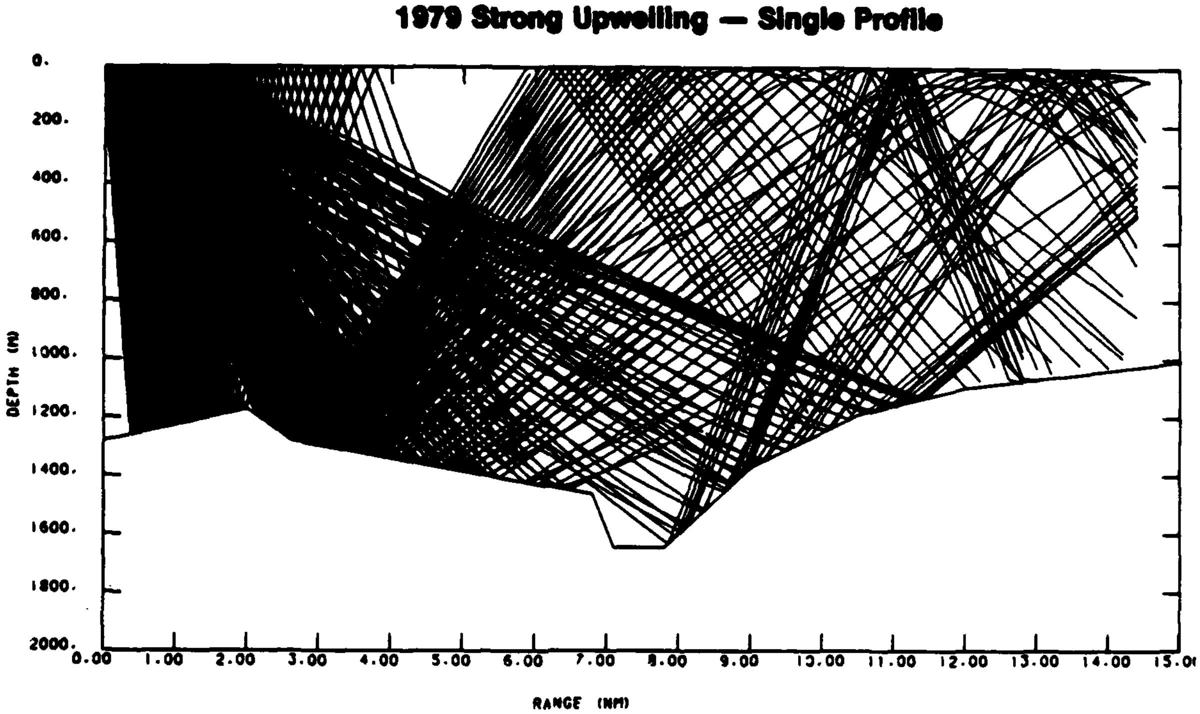
LINE FROM POINT A TO POINT B INDICATES DIRECTION OF ACOUSTIC PATH UNDER INVESTIGATION.

Slide 4

For several years, Professor Traganza and others at the Naval Postgraduate School have studied the oceanographic properties of the upwelling region off the coast of California at Point Sur.

Temperature contours are shown in slide 4 for the upwelling in a fully developed state. The core of coldest water is quite localized and occurs at the end of an underwater canyon, which may facilitate the influx of cold water.

We have selected the track A-B, running parallel to the coast and through the upwelling core, for acoustic modeling based on the temperature data. The ray diagrams that follow will have the receiver located at A.

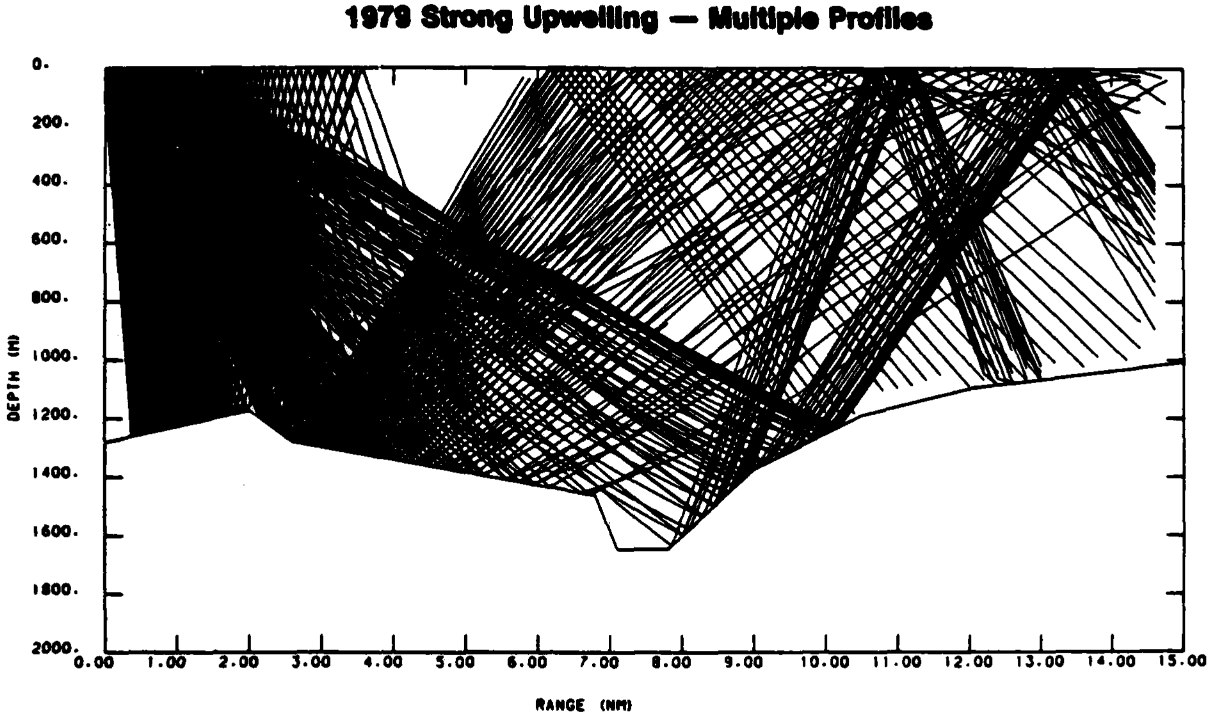


Slide 5

First, we used only a single sound-speed profile, located at A; so we could determine the general propagation conditions, especially the effect of the sloping bottom.

For practical reasons, we chose a receiver depth of 100 m for this initial study. The resulting ray diagram is shown in slide 5. We have chosen to use ray diagrams so that we can see how the energy is distributed throughout the water column. We don't know the bottom properties well enough to really trust absolute level predictions.

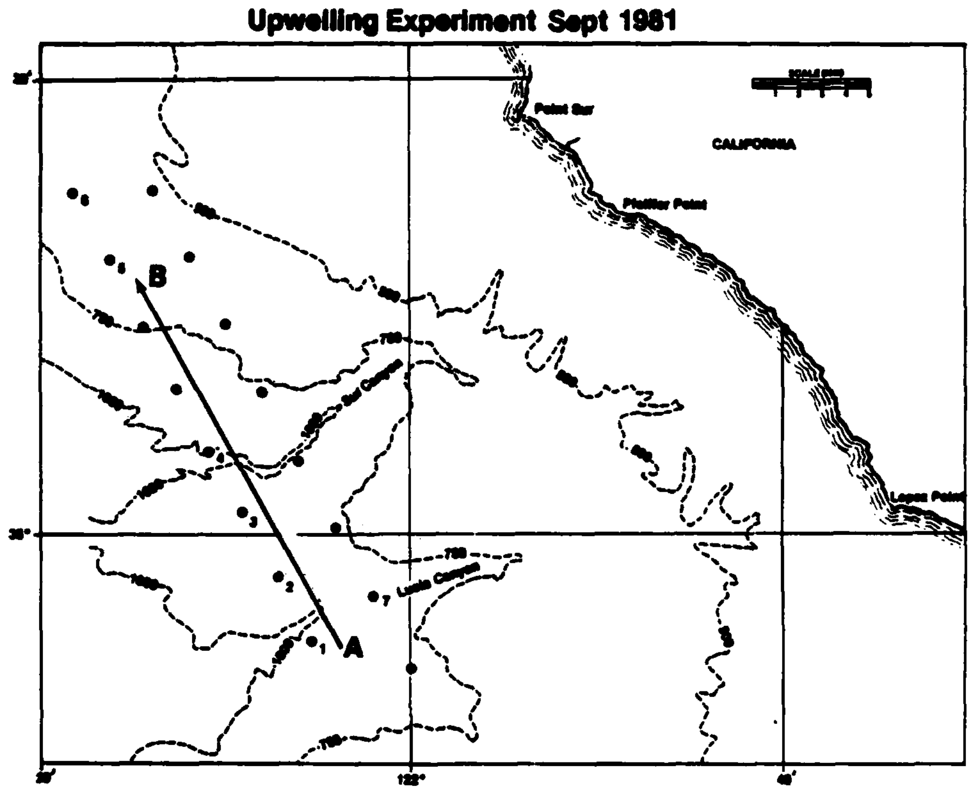
For these conditions, all rays shown interact with the bottom. Of particular interest will be the limiting ray, which strikes the bottom at a range of approximately 11.5 nmi. The corresponding reflected ray has not reached the surface as it passes off scale at 15 nmi.



Slide 6

We now introduce the effect of the upwelling, slide 6, by running the model again with a series of sound-speed profiles, representing the range-dependent cross section of the upwelling along the track.

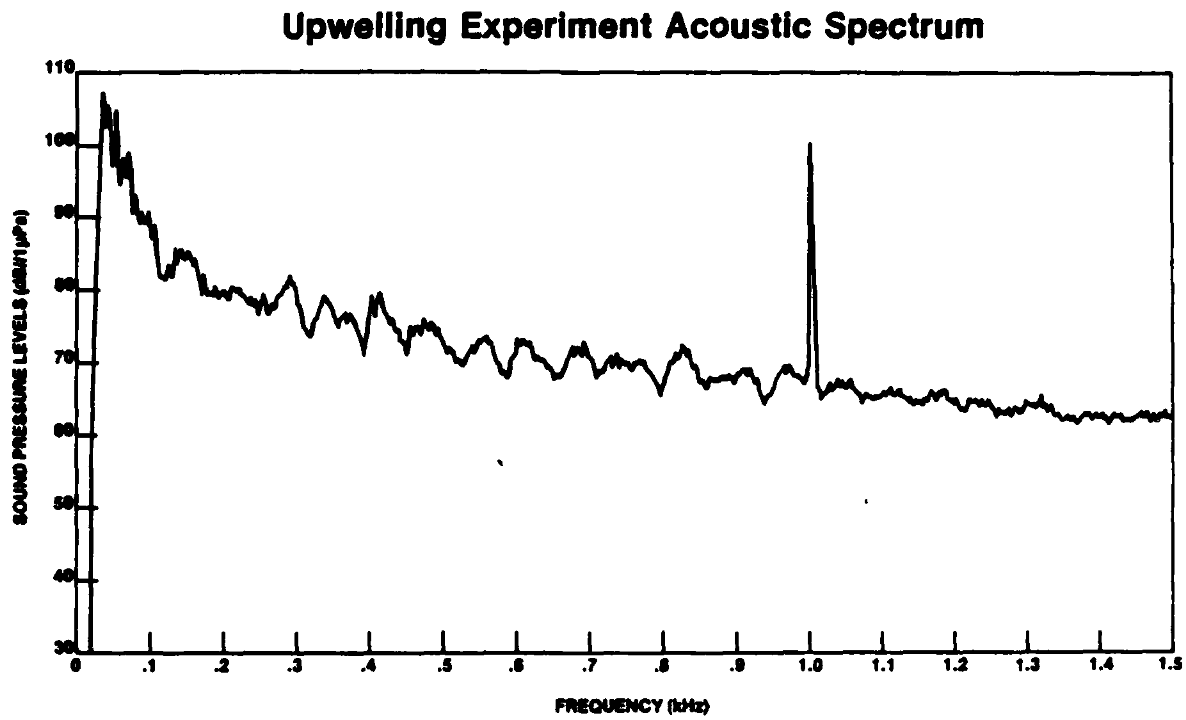
In general, the ray pattern is quite similar to the single-profile case. Note again, however, the limiting ray, which strikes the bottom at a range of 10 nmi, rather than 11.5 nmi. Since this is a region of rapidly changing bottom slope, the reflected angle is changed even more, with the resulting rays reaching the surface at a range now of 13.5 nmi. In this particular case, the bottom slope acts to enhance the effect of the upwelling on acoustic propagation.



Slide 7

In September of last year, we conducted an experiment to measure sound propagation through this upwelling. After an oceanographic survey to determine the state of the upwelling at this time (which we found to be weakly developed), we had a P-3 aircraft drop a calibrated sonobuoy pattern, shown by the black dots in slide 7, across the upwelling.

We then had R/V ACANIA tow a 1000-Hz source at a depth of 100 m through the sonobuoy pattern along the track shown by the solid line, starting at A. Signals were received on the aircraft from all sonobuoys and were recorded, then later processed.

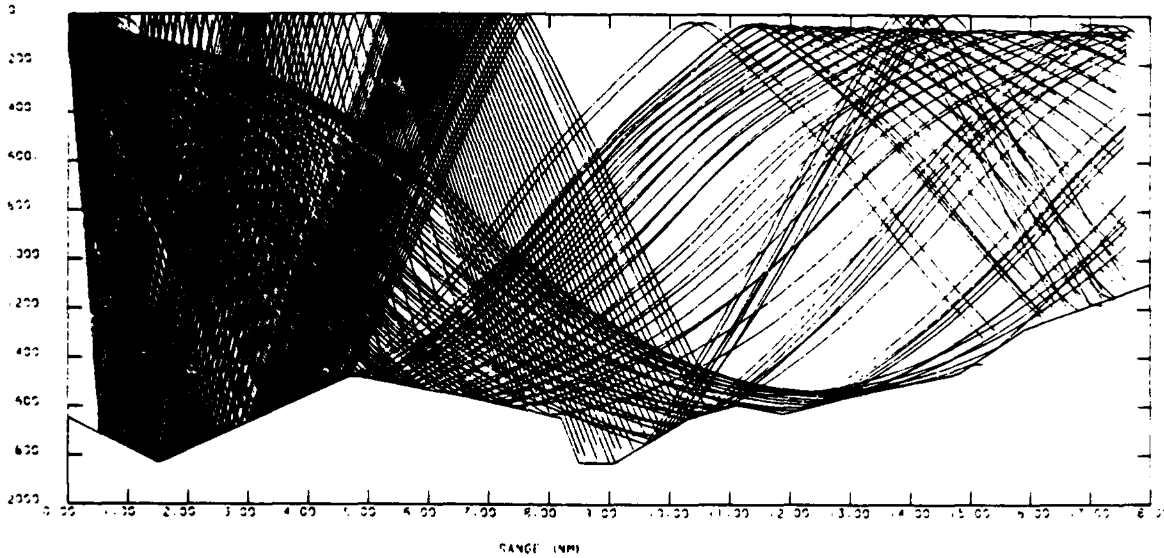


Slide 8

We kept our source level low enough to prevent overloads but still had an excellent signal-to-noise ratio, as the spectra of a typical received signal in slide 8 shows.

One reason for initially choosing a frequency of 1 kHz was to avoid interference from shipping noise and you can see that it was not a problem.

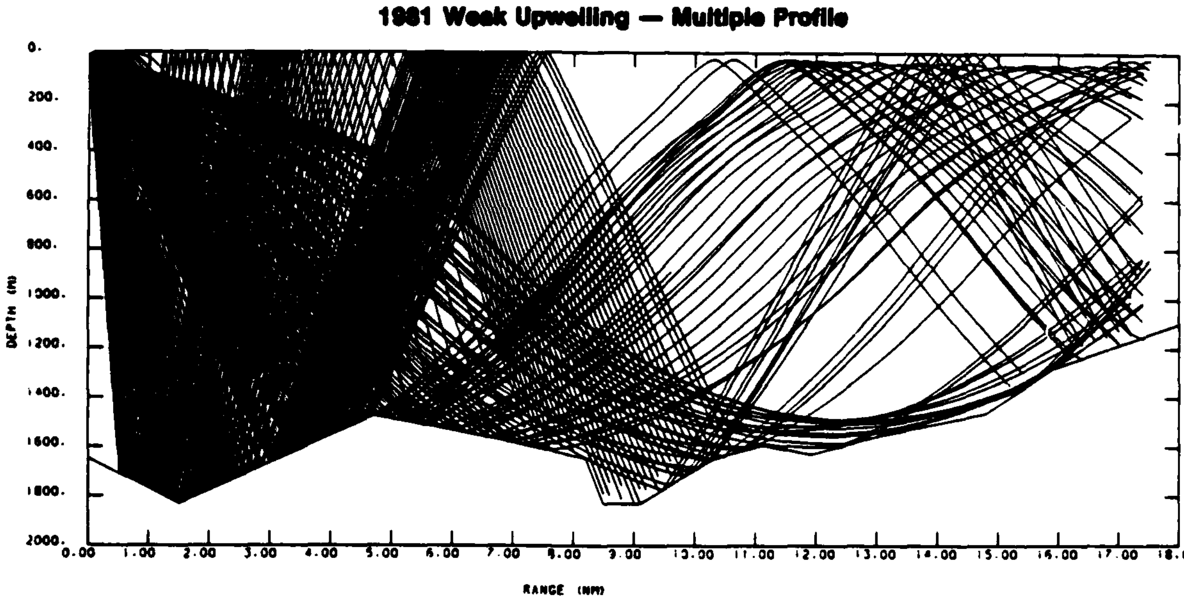
1981 Weak Upwelling — Single Profile



Slide 9

Using the environmental data from the survey, we obtained modeling predictions as we had done previously. Slide 9 is the ray diagram for a single profile taken at a receiver site near the beginning of the tow track. Note that this track is slightly further offshore than the previous one, hence there is a greater average water depth (1600 m versus 1200 m).

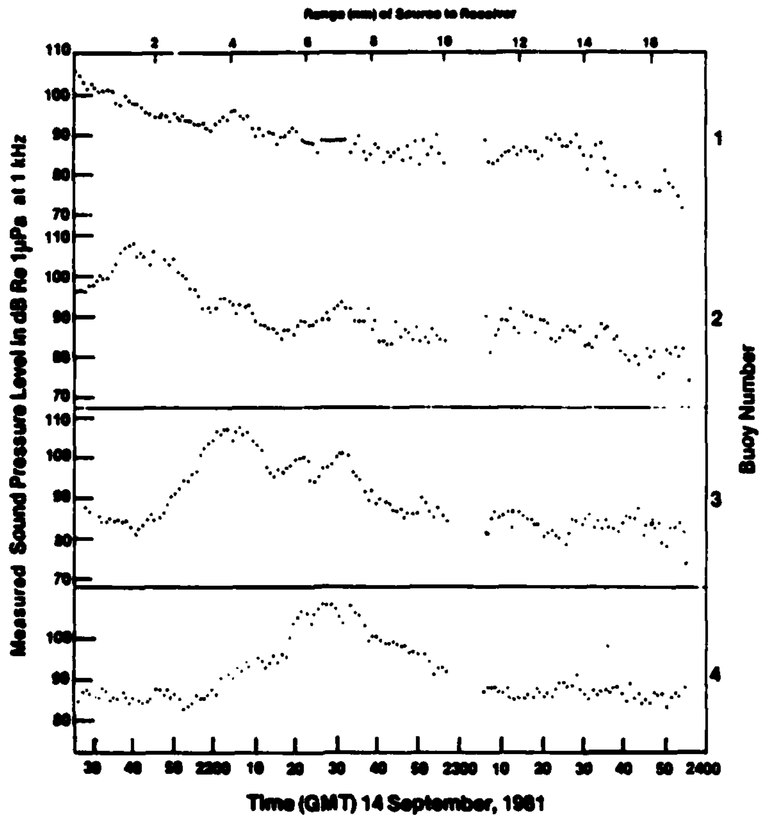
Indicative of the high variability of this region, this slight shift of track caused a significant propagation change, totally refracted rays. Again, the limiting ray is of interest. It does not strike the bottom but its ray bundle, say at 14 nmi, is quite weak and diffuse.



Slide 10

Repeating the modeling with a series of sound-speed profiles across the upwelling again, we see in slide 10 that the pattern is not greatly changed. But look at the limiting ray bundle at 14 nmi. There is significant strengthening and focusing due to the upwelling.

Unfortunately, this ray diagram also shows that the choice of a 100-m source depth will not see this ray bundle. In fact, the propagation loss from this configuration will be rather unspectacular.



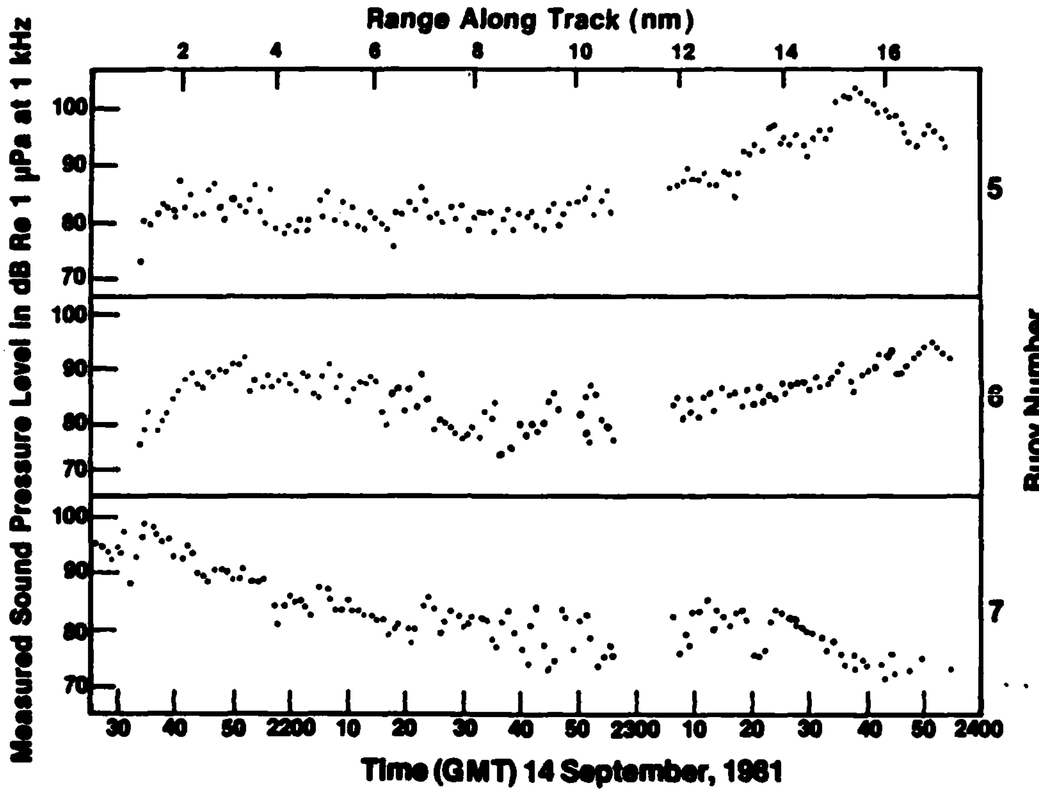
Slide 11

The data we received from the sonobuoys were plentiful, consistent, and, as predicted, unspectacular. In slide 11, data from four different sonobuoys are presented; sonobuoy 1, shown at the top, was located at the start of the projector run. We have added the appropriate range scale. Sonobuoy 2 was located 2 nmi up the track, sonobuoy 3 was at 4 nmi, and sonobuoy 4 was at 6 nmi.

You can see the sound-pressure level reach its peak as the source consecutively passes by each sonobuoy.

The data gap for all sonobuoys at time 2300 hr is due to having to change tape on the airplane's recorder.

In general, there are level increases at 4 and 24 nmi as particular groups of bottom-reflected rays reach 100 m.



Slide 12

Sonobuoy 5 is located at the other end of the track (slide 12); so its data are a mirror image of those from sonobuoy 1, located at the beginning.

Sonobuoy 6 is 2 nmi further out; so the source did not make it that far but we do see better the signal increase that occurs at a range of 14 nmi.

Sonobuoy 7 was located opposite to sonobuoy 1 at the beginning of the track; so the data should be essentially the same, which they are.

Slide 13

From what we have learned about upwellings to date, what conclusions can be made?

Oceanographers have obtained a significant amount of data on upwellings and, we feel, would agree with us on the following points (slide 13):

1. Upwellings can produce strong horizontal temperature gradients;

2. Certain locations favor the formation of upwellings;

3. Bottom topography is a factor in determining these locations; and

4. There is seasonal variability in the occurrence of upwellings and day-to-day variability in an upwelling when it is formed.

CONCLUSIONS ON UPWELLINGS

ACOUSTIC

- SMALL REFRACTION EFFECTS
- EFFECTS MAGNIFIED BY SLOPING BOTTOM
- GREATEST EFFECTS ON CAUSTICS
- SOURCE/RECEIVER AND UPWELLING DEPTH CRITICAL
- COMPARISON OF THEORY/MEASUREMENT DIFFICULT
  - TIME VARIABILITY OF UPWELLING
  - ACOUSTIC MODELING PRECISION

OTHER ACOUSTIC EFFECTS

- DESTROY SURFACE DUCT MODE
- MODIFIES CONVERGENCE ZONE MODE

Slide 14

Regarding acoustic effects, we believe we can offer some conclusions from the limited amount of modeling and measurements we have done so far (slide 14):

1. Refraction effects are small but can be relatively significant;

2. Such effects can be enhanced by the bottom slope;

3. The greatest effect appears to be a caustic region;

4. Source, receiver, and water depth are critical to create effects or avoid them; and

5. High spatial and temporal variability of coastal upwelling regions challenges modeling capabilities.

Finally, two other points from other investigators are worth mentioning:

1. Strong upwellings can destroy surface channels; and

2. Upwellings can modify convergence-zone propagation.

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